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FINAL REPORT

Office of Naval Research
Contracts Nos. Nonr-401(21)
and Nonr-2883(00)

AVIATION CRASH INJURY RESEARCH

October 1, 1955
through
September 15, 1959

Aviation Crash Injury Research
A Division of
Flight Safety Foundation, Inc.
2713 East Airline Way
Sky Harbor Airport
Phoenix, Arizona

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FOREWORD

Aviation Crash Injury Research, from October 1, 1955 through March 31, 1959, was administered by Cornell University under ONR Contract Nonr-401(21) and was known as Aviation Crash Injury Research of Cornell University. On April 1, 1959, administration of the project was transferred to the Flight Safety Foundation, Inc., under Contract Nonr-2883(00). The latter contract terminated on September 15, 1959.

AvCIR was located at LaGuardia Airport, Flushing, New York, from the beginning of the reporting period to the end of September 1957. During the first half of October 1957 the project moved to Sky Harbor Airport, Phoenix, Arizona.

During the period covered by this report, AvCIR's major financial support has been from the Departments of the Army, Navy and Air Force. The CAA (now FAA) contributed financial support during part of this period and has for a number of years been the project's major source of data on lightplane accidents. In addition, various industrial and aviation organizations have contributed funds and, since April 15, 1959, the project also has benefitted by a grant from the National Institutes of Health.

OBJECTIVES AND TASKS

The principal objective of Aviation Crash Injury Research has been to provide data which could be used to improve crash survival design of aircraft, thereby increasing the survival rate in many aircraft accidents.

To attain this objective, AvCIR has performed the following tasks:

1. Investigated, analyzed and published reports on the related accident and medical details of survivable crashes involving transport, general, and some military aircraft.
2. Provided general recommendations and precepts regarding design aimed at (a) improving the crashworthiness of basic aircraft structure, (b) improving the protective qualities of seats, safety belts, shoulder harnesses, helmets, and interior cabin and cockpit components, and (c) improving the protective qualities of personal equipment through modification, wherever possible.
3. Cooperated and consulted with appropriate government agencies, safety groups, airframe and equipment manufacturers, and airline operators regarding crash-survival design.
4. Cooperated with appropriate government agencies and safety organizations in the initiation and operation of crash survival investigative groups within the framework of existing national and international aircraft accident investigating agencies.
5. Stimulated other agencies to conduct research aimed at providing data needed for improved crashworthy and crash-survival design.
6. Participated in safety design committees having direct interest in crash-survival design problems.
7. Participated in educational work aimed at indoctrinating engineers with crash-survival concepts.
8. Endeavored to stimulate other agencies to conduct dynamic testing of tie-down and other passenger and pilot protective devices.
9. Designed field reporting forms for obtaining and recording crash-injury details of aircraft accidents.
10. Promoted the use of shoulder harness for flight crew members

of transport aircraft and for all occupants of liaison and general aircraft.

11. Assisted in the training of investigators in techniques and procedures used in observing and recording crash-injury details in survivable aircraft accidents.
12. Received, analyzed and compiled crash-injury reports from case material supplied by accident investigators of Federal and State agencies and the U. S. Army.
13. Designed, published, and issued to all interested agencies medical reporting forms designed to provide more concise survivor and post-mortem data needed for crash-survival study.
14. Initiated the publication of papers and other related text for a Crash Survival Design Manual.
15. Conducted statistical and qualitative analyses of accident-injury cases involving transport, general, and Army aircraft.

FIELD INVESTIGATION OF ACCIDENTS

During the period of this report the following accident investigations were made:

U. S. Army Accidents

11/30/55	L-19A	Carroll Island, U. S. Army Chemical Center, Maryland
1/ 4/56	L-19A	Fort Rucker, Alabama
6/ 5/56	L-19	Fort Bragg, North Carolina
6/22/56	H-13	Monmouth County Airport, Belmar, New Jersey
6/21/56	L-19A	Selma, Alabama
1/20/57	L-20A	Fort Devens, Massachusetts
4/11/57	L-23E	Colorado Springs, Colorado
5/24/57	L-20	Fort Monmouth, New Jersey
6/17/57	L-20	Fort Rucker, Alabama

7/31/57	H-21C	Fort Riley, Kansas
7/15/58	L-19	Fort Huachuca, Arizona
9/19/58	L-20	Phoenix, Arizona
6/ 6/59	U-1A	Fort Carson, Colorado

U. S. Navy Accidents

3/27/56	S2F-1	Masontown, Pennsylvania
9/13/56	T-34B	Brewton, Alabama
10/ 5/56	F-11-F-1	Peconic River Facility, Grumman Aircraft Corporation

Civil Aircraft Accidents

2/20/56	Capital Airlines, Viscount	Chicago, Ill.
2/17/56	Eastern Airlines, Martin 404	Owensboro, Ky.
4/ 1/56	TWA, Martin 404	Pittsburgh, Pa.
11/15/56	TWA, Martin 404	Reno, Nev.
11/30/56	Sikorsky S-58	New York, N. Y.
1/ 6/57	American Airlines, Convair 240	Tulsa, Okla.
2/ 1/57	Northeast Airlines, DC-6A	New York, N. Y.
3/10/57	Eastern Airlines, Martin 404	Louisville, Ky.
5/ 3/57	Piper PA-23	Teterboro, N. J.
1/ 7/58	Taylorcraft BC-12	Mesa, Ariz.
3/25/58	Braniff Airlines, DC-7C	Miami, Fla.
8/27/58	Stearman N2S Cropduster	Queen Creek, Ariz.
2/ 3/59	American Airlines, Electra	New York, N. Y.

EVALUATION OF AIRCRAFT AND AIRCRAFT COMPONENTS

In March 1958, Mr. Hasbrook made a crash-safety evaluation of a DC-3 belonging to Goodyear Aircraft Corporation. Since then, most of the recommendations have been accepted and incorporated into this aircraft so that it now represents one of the most crashworthy aircraft of its type in operation today.

In February 1958 a photographic evaluation was made of an Army L-20 Beaver (De Havilland) and a report submitted outlining potential crash-injury hazards and recommended means of redesigning or de-lethalizing them. An evaluation was also made of an Army L-19 (Cessna). Both evaluations were at the request of the Army Electronic Proving Ground, Ft. Huachuca, Arizona.

Earlier, an evaluation was conducted of a mock-up of the XH-40 Army Utility Helicopter at Bell Aircraft Corporation, Fort Worth, Texas. A thorough crash-survival evaluation produced an AvCIR report describing 27 items affecting, in varying degrees, survival. Recommendations were made for improvements of the indicated hazards and, in addition, a proposal was made for studies which might be undertaken by the manufacturer to improve the inherent crashworthiness of the XH-40 and other similar type helicopters.

ACCIDENT-INJURY REPORTING AND ANALYSIS

The Fixed Wing Accident-Injury Report Forms were subject to major revision and completely new Helicopter Report Forms were developed. These then were made available for use by investigators of the U. S. Army and

Federal aviation agencies, particularly CAA (now FAA) and several interested State groups.

Through the use of these forms a growing file is obtained on case material which is transferred to an IBM analytical system for quantitative statistical analysis. This covers both Army and civilian accident cases.

Along with the development of new report forms has been the development of new IBM codes for both Fixed Wing and Helicopter accident-injury analysis. These codes have been tested and re-tested so that now they are satisfactory for analytical use.

A major undertaking during this reporting period has been the transfer of data from a McBee card system to an IBM system. Considerable progress has been made with this, with substantial assistance also being obtained through a grant of funds by the National Institutes of Health as of April 15, 1959.

Sufficient data were transferred to permit a statistical analysis dealing with the severity of injury in lightplane accidents, including studies of injury rates, aircraft damage, accident severity, impact angle and impact speed, involving 1596 persons in 913 lightplane accidents. A preliminary report has been prepared. A final report will be issued later.

CRASH SURVIVAL DESIGN MANUAL

Work was begun late in 1955 on a Crash Survival Design Manual, a loose-leaf publication which is divided into three sections, (1) Crash

Survival Design Precepts, (2) Design Tip Sheets, and (3) Engineering Data Sheets. A number of Design Tip Sheets, Human Factors Sheets and a section on crash survival design entitled "The Design of Passenger Tie-Down" have been issued to date.

TRAINING IN CRASH-INJURY ACCIDENT INVESTIGATION

With the increased interest on the part of the Transportation Corps, Department of the Army, in the potential offered by crash-injury investigation and analysis, a demand was created for a facility for training Army personnel. This resulted in the establishment at AvCIR of a Crash-Injury Investigator's School and the inauguration of a series of 2-week training courses.

The curriculum of the Crash Injury Investigator's Course is rather unique in that the course material is suited to the needs of design engineers, pilots and physicians, as well as safety specialists and accident investigators, each of whom may have little or no background or experience in the field of the other.

The concept of crash survival design is taught in various phases; these include instruction in accident-injury investigation, mathematics, report writing, applied physics, medical and physiological problems, analyses of crash forces, etc.

Actual field problems are utilized; two crashed airplanes have been set up as training aids in field investigation in realistic surroundings at nearby Williams Air Force Base. In addition, several late model Army and Air Force helicopters and fixed-wing aircraft are used for evaluation of both protective and hazardous design features.

The first course was inaugurated in October 1958. Sixteen students from the U. S. Army, the CAA (now FAA), CAB, Arizona State University and one domestic airline attended this initial course.

The second course was conducted in March 1959, with six Army Flight Surgeons and five Army Aviation Safety Officers, along with representatives from Convair, Boeing and Lockheed graduating from the course.

A third course, in May 1959, graduated seven Aviation Safety Officers, five Flight Surgeons, a CAB Engineering Division Airworthiness Inspector and the Flight Safety Supervisor of Trans-World Airlines.

MISCELLANEOUS AND GENERAL

Accompanying the specific activities cited previously, many corollary activities also took place. As an example, Mr. A. Howard Hasbrook, Director, served on the Committee on Operating Problems and the Subcommittee on Flight Safety of the National Advisory Committee for Aeronautics; also, as a Member and Secretary of the S-9 Committee on Cabin Safety of the Society of Automotive Engineers.

Numerous conferences were held with representatives of aircraft and accessory manufacturers and designers, many safety conferences and committee meetings were attended, and the Director presented numerous papers before professional organizations. As an example, a technical paper was presented by Mr. Hasbrook at the 19th Meeting of AGARD at the Medical Panel in Paris in April 1957, at the request of the Departments of the Navy and Air Force. Most recently, Mr. Hasbrook, the Director, presented a

paper before the Annual Convention of the International Association of Insurance Counsel on the subject of "Crash Safety Design Can Affect You," June 30, 1959. Citation of specific meetings, conferences, lectures and papers will be found in previous Annual Reports made under the ONR Contract.

On November 12, 1958 Mr. Hasbrook, Director of Aviation Crash Injury Research, was presented the Flight Safety Award at the 11th Annual Air Safety Seminar in Atlantic City, N. J. The presentation was made for "distinguished service in achieving safer utilization of aircraft." Recipients are selected by air safety specialists, the Flight Safety Foundation, and the aviation industry at large.

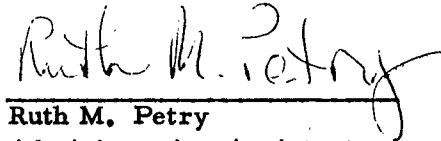
These varied activities have resulted in numerous publications. These are identified in Appendix A.

Progress and Activity Reports issued previously under this contract can be identified as follows:

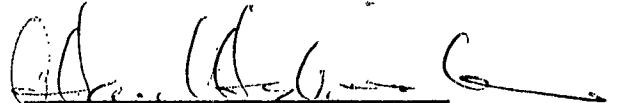
- A. A Progress Report on a Preliminary AvCIR Study of the Problems Associated with a Crash Injury Research Program in the Field of Helicopter and Steep Gradient Aircraft, For the Department of the Army, for the period December 1, 1955 through June 30, 1956 (July 1956)
- B. Activities Report, Aviation Crash Injury Research of Cornell University, February 15, 1956 through August 15, 1957 (November 1957)
- C. Annual Report, Aviation Crash Injury Research of Cornell University, August 15, 1957 through November 15, 1958 (undated)

I certify that the information contained in this
Final Report on ONR Contracts Nos. Nonr-401(21) and Nonr-2883(00)
is complete and correct, to the best of my knowledge.

January 11, 1960


Ruth M. Petry
Administrative Assistant

Approved


A. Howard Hasbrock
Director, as of September 15, 1959

APPENDIX A

AvCIR PUBLICATIONS

- "AvCIR Photographic Report: Braniff CV 340." (AvCIR-2-PR-59).
A. H. Hasbrook and J. T. Pairn, October 1955.
- "AvCIR Evaluation Report on the Bell XH-40 Mock-up." (AvCIR-4-PV-60).
A. H. Hasbrook, December 1955.
- "AvCIR Photographic Report on L-19." (AvCIR-3-PR-62). A. H. Hasbrook
and J. T. Pairn, February 1956.
- "Preliminary AvCIR Photographic Report on Eastern Airlines Martin 404,
Owensboro, Kentucky." (AvCIR-4-PR-63). A. H. Hasbrook and
J. T. Pairn, June 1956.
- "Helicopter Accident and Injury Report Form AC (Preliminary)." AvCIR-
5-F-64). May 1956.
- "Boeing 707 Evaluation." (AvCIR-1-V-65). A. H. Hasbrook, June 1956.
- "Design of Passenger 'Tie-Down'." (AvCIR-44-O-66). A. H. Hasbrook,
September 1956.
- "General Design Requirements for Crashworthiness and Delethalization of
Passenger Transport Aircraft." (AvCIR-45-O-67). A. H. Hasbrook,
August, 1956.
- "AvCIR Photographic Report of U. S. Army Bell H-13 Helicopter Accident,
Monmouth County Airport, N. J." (AvCIR-5-PR-68). A. H. Hasbrook,
December, 1956.
- "A Progress Report on a Preliminary AvCIR Study of the Problems Asso-
ciated with a Crash Injury Research Program in the Field of Helicopter
and Steep Gradient Aircraft, for the U. S. Army, for the Period
12/1/55 through 6/30/56." (AvCIR-46-O-69). A. H. Hasbrook,
June, 1956.
- "'HV' Harness and Reel Questionnaire." (AvCIR-6-F-70). October 1956.
- "Final Progress Report, Office of Naval Research Contract #N6onr 264-12,
Covering Period from 7/1/48 through 9/30/55." (AvCIR-47-O-71).
September, 1956.

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- "An AvCIR Preliminary Report on a Study of Injury Rates in Survivable Type Accidents Involving Eight Personal Type Aircraft of Various Models." (AvCIR-4-SS-72). A. H. Hasbrook, S. Macri, and M. Haberman, September 1956.
- "Photo and Caption Release of F-11F-1." (AvCIR-1-PCR-73). A. H. Hasbrook and J. T. Pairn, October 1956.
- "Photo and Caption Release of H-13." (AvCIR-2-PCR-74). A. H. Hasbrook, July 1956.
- "Photo and Caption Release of T-34B." (AvCIR-3-PCR-75). A. H. Hasbrook and J. T. Pairn, November, 1956.
- "Photo and Caption Release of 'HV' Harness Mock-up." (AvCIR-4-PCR-76). A. H. Hasbrook, November 1956.
- "Photo and Caption Release of TWA Martin 404." (AvCIR-5-PCR-77). A. H. Hasbrook, J. T. Pairn, December 1956.
- "AvCIR Aero-Commander Report (Army)." (AvCIR-48-O-78). A. H. Hasbrook, December 1956.
- "The Bio-Mechanical Analyses of Survivable-Type Aircraft Accidents as a Factor in Improving Safety." (AvCIR-49-O-79). A. H. Hasbrook, January 1957.
- "Photo and Caption Release of CV 240, American Airlines, Tulsa, Oklahoma." (AvCIR-6-PCR-80). A. H. Hasbrook and J. T. Pairn, January 1957.
- "AvCIR Crash Survival Study of U. S. Army Bell H-13 Accident at Monmouth County Airport, Belmar, N. J., June 21, 1956." (AvCIR-H-5-CSS-81). A. H. Hasbrook, J. T. Pairn, and H. R. Guggenheimer, February 1957.
- "Crash Injury Research - A Means for Greater Safety in Accidents." (AvCIR-50-O-82). A. H. Hasbrook, March 1957.
- "Designing for Survival in VTOL Aircraft." (AvCIR-51-O-83). A. H. Hasbrook, March 1957.
- "Photo and Caption Release of Martin 404 Eastern Airlines, Louisville, Kentucky." (AvCIR-7-PCR-84). A. H. Hasbrook, March 1957.

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"The Need for Crash Safety Design in Crew Member Stations in Transport Aircraft." (AvCIR-52-O-85). A. H. Hasbrook, March 1957.

"Helicopter Accident and Injury Report Form." (AvCIR-7-F-86).
June 1957.

"A Review of Crashworthy Design in Light Aircraft." (AvCIR-53-O-87).
W. R. Knowles, June 1957.

"AvCIR Analysis and Photographic Report - U. S. Army Beechcraft L-23
Accident, Colorado Springs, Colorado." (AvCIR-6-PR-88).
A. H. Hasbrook, J. T. Pairn, and H. R. Guggenheimer, August
1957.

"Crash Injury Report for U. S. Army Safety Division." (AvCIR-54-O-89).
A. H. Hasbrook, September 1957.

"AvCIR Helicopter Crash Injury Report Form." (AvCIR-7-F-86).
November 1957.

"AvCIR Analysis and Photographic Report, New York Airways Sikorsky S-58
Accident, La Guardia Airport, Flushing, New York, November 30,
1956." (AvCIR-7-PR-95). A. H. Hasbrook, H. F. Roegner, and
W. R. Knowles, April 1958.

"Gross Pattern of Injury of 109 Survivors of Five Transport Accidents."
(AvCIR-5-SS-96). A. H. Hasbrook, July 1958.

Preliminary Report - "Headings for IBM Coding of Crash Injury and Sur-
vival Data from Helicopter and Lightplane Accidents." A. H. Has-
brook, S. Macri, and M. H. Piazza, August 1958.

"AvCIR Fixed-Wing Crash-Injury Report Form." (AvCIR-8-F-92).
August 1958.

Preliminary Report - "Bar Charts of McBee-IBM Data." November 1958.

"Preliminary Photographic Evaluation Report of Braniff Accident for ALPA."
(AvCIR-8-PR-100). J. Carroll and H. F. Roegner, December 1958.

"Human Impact Survival at 162g." (AvCIR-58-O-101). A. H. Hasbrook,
March 1959.

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"Greater Air Safety through Crash Safety Design." (AvCIR-59-O-102).
A. H. Hasbrook, April 1959.

"The Importance of Designing for Crash Safety in Rotary-Wing Aircraft."
(AvCIR-60-O-103). W. R. Knowles, May 1959.

"Preliminary Photographic Evaluation of Otter Accident, Fort Carson,
Colorado." (AvCIR-9-PR-104). A. H. Hasbrook, J. Carroll,
H. F. Roegner, G. M. Bruggink, and W. R. Knowles, September
1959.

"Principles of Crash-Injury Investigation." (AvCIR-62-O-107). J. Carroll,
September 1959.

"Human Factors, the Basis for Crash Safety Design." (AvCIR-63-O-108).
A. H. Hasbrook, September 1959.

"Severity of Injury in Lightplane Accidents; A Study of Injury Rate, Air-
craft, Damage, Accident Severity, Impact Angle, and Impact Speed
Involving 1596 Persons in 913 Lightplane Accidents." (AvCIR-6-SS-
105). A. H. Hasbrook, July 1959 (unpublished).